Input to

U.S. House of Representatives Committee on Science

On the topic of

Strengthening Windstorm Hazard Mitigation: An Examination of Public and Private Efforts

Testimony given at
Lubbock, Texas
February 9, 2004

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Windstorm Hazard Mitigation – An Effective Approach

The Potential of Research

The common interest that brings us together is curbing the spiraling losses inflicted upon our country by windstorms. My presentation and report focus largely on one applied research program at Texas Tech University that has proven effective. This program has produced results that are being used by facilities designers to provide occupant protection and to mitigate the effects of windstorms. The model's importance lies not in what has been accomplished—albeit significant as a pioneering effort—but rather to reveal what might be achieved when this model is expanded from a synergistic labor of a few researchers to a focused, coordinated effort among many diverse teams working toward a common goal at several of our leading research and implementation institutions.

Losses

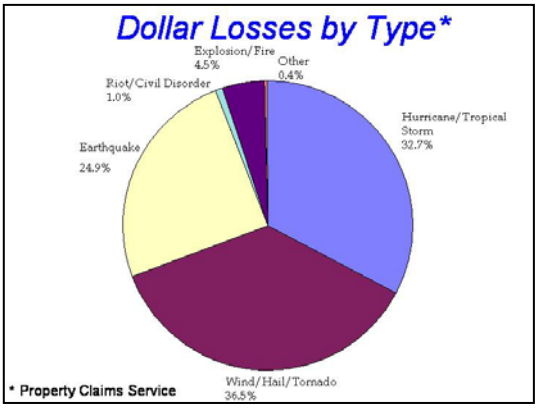
The death, destruction, and disruptions associated with windstorms are felt by all. And while consistent databases on damage and economic impacts are lacking, we can draw conclusions about the increasing devastation and waste of the windstorm hazard. For example, of the ten most costly catastrophes in the U.S., eight are weather-related. In the past 25 years, the U.S. has experienced 57 weather-related disasters in which damages exceeded $1 billion. The total normalized losses from these events totals over $355 billion.

Most Costly Catastrophes

(Adjusted to 2002 dollars)

Aug.	1992	Hurricane Andrew	$19.9 billion
Jan.	1994	Northridge Quake	$15.2 billion
Sep.	1989	Hurricane Hugo	$6.1 billion
Sep.	1998	Hurricane Georges	$3.3 billion
Sep.	1965	Hurricane Betsy	$2.9 billion
Jun.	2001	Tropical Storm Allison	$2.5 billion
Oct.	1995	Hurricane Opal	$2.5 billion
Mar.	1993	Winter Storms	$2.2 billion
Oct.	1991	Oakland, Ca. Fire	$2.2 billion
Apr.	2001	Tornado storm	$2.2 billion

Windstorms are prominent among natural hazards, accounting for about two-thirds of the total losses. The percent of insured losses shown in the pie chart are for the ten year period of 1985-95. Figures in this form are not available beyond 1995.



Population growth, urbanization, and increased property values in harm's way will push future economic losses even higher. We can curb these losses through large-scale, coordinated, multi-disciplinary research connected to effective implementation strategies. Such programs will, over time, have large benefit-to-cost ratios.

Past investments in research and technology have produced improved prediction and warning systems, reducing death and injuries resulting from windstorms. Better warnings have facilitated evacuations from hurricanes, moving people out of harm's way. But population growth has made evacuation less viable in some regions, forcing an alternative strategy—sheltering in place. This is a good strategy for alleviating problems associated with evacuation, but will

prove effective only if a sufficient number of shelter spaces are available. Shelter deficits are large in some areas. Without protective shelters that can withstand extreme winds and windborne debris, large-scale casualties are likely, reversing the decreasing death rate of recent decades. Much research is needed toward economical and safe shelter design and cost-effective mitigation of property losses.

Evacuation?

National Research Needs

Recent reports by various agencies help define the research needed to abate the windstorm hazard. Over the years, the National Research Council has published a number of useful reports that define the wind hazard and point to needed research. Most recently the RAND report, presented at this hearing by Charles Meade, clearly illuminates needed research and some challenges in implementation. The report of the American Association for Wind Engineering, prepared and presented by Dr. Bogusz Bienkiewicz, yields data emphasizing the importance of mitigation efforts and presents details of a proposed national program for mitigating the effects of windstorms.

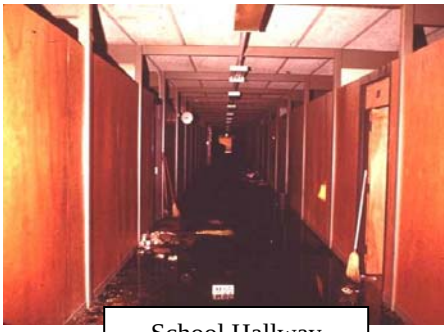
This report, presented by Texas Tech University, deals primarily with progress made in some research areas along with challenges and future opportunities for further research in those areas, and it shows some facilities that are available for continued use by the research community. Technology transfer and education is a significant component of the ongoing effort at Texas Tech University.

Windstorm Hazard Mitigation at Texas Tech: An Overview

Windstorm hazard mitigation research and development started at Texas Tech University on May 11, 1970 when a severe tornado affected half the constructed facilities of the city of Lubbock, killing 26 people and injuring more than 500. A team of researchers from the Civil Engineering Department at Texas Tech joined forces with a special committee of the National Research Council in documenting damage and destruction of buildings by wind forces of the tornado. Since 1970, university personnel have documented and archived damage photographs and other data in more than 130 windstorm events.

The Institute for Disaster Research (IDR) organized and coordinated early programs in windstorm hazard mitigation at Texas Tech. In the 1970s, the Institute pursued research in the destructive nature of tornado and hurricane winds on buildings, enabling them to provide information to:

- The National Weather Service - opening windows in tornadoes does not help
- The Nuclear Regulatory Commission - credible size of windborne debris
- The public - safest places in houses are in a small central room
- School officials - inside hallways are the best areas to seek refuge; avoid large span gymnasiums.



School Hallway

Gymnasium

Under the sponsorship of the National Science Foundation (NSF), Defense Civil Preparedness Agency (currently FEMA), National Severe Storms Laboratory (NSSL) and the State of Texas, the Institute published papers, reports, and guidelines for occupant protection and engineering perspectives of tornadic storms.

In the 1980s, with the change of our name to the Wind Engineering Research Center, personnel of the center continued research in wind effects on buildings and the implications of damage. Significant items of technology transfer included the upgrading of wind load standards (chaired the ANSI A 58.1 and ASCE 7 Wind Load Committees), defining consequences of window glass breakage due to windborne debris, and assessing high roof corner pressures obtained in field experiments.

The research program expanded in the 1990s to include meteorology and damage economics; the Center changed its name to Wind Science and Engineering (WISE) Research Center in order to reflect the multidisciplinary approach into which it had evolved. One of the significant research pursuits was the ten-year Cooperative Research in Wind Engineering between Colorado State University and Texas Tech University, which was funded by the National Science Foundation (NSF). This research effort was multidisciplinary and involved fifteen faculty members from the two institutions. The cooperative basic research permitted expansion of research in ground-level wind characteristics, wind damage economics, and wind tunnel and field studies for low-rise building loads. Technology transfer was accomplished for shelter design, leading to prescriptive designs for residential shelters, published by the Federal Emergency Management Agency (FEMA). Implementation of storm shelter (Safe Room) research resulted in the birth of the storm shelter industry and the formation of the National Storm Shelter Association (NSSA) who foster quality in the shelter industry. The Cooperative program also produced building damage prediction models through development of an expert system, established the Information Outreach Center, and graduated students well-versed in windstorm damage and mitigation.

Multidisciplinary research in the WISE Center continues under the sponsorship of the National Institute of Standards and Technology (NIST) and other agencies and private organizations. Currently, faculty members in engineering, atmospheric science, economics, mathematics, and architecture are involved in wind-related research. The facilities of debris impact testing, field site (with a 200-meter tower) at Reese Technology Center, West Texas Mesonet, portable meteorological towers including the SMART radar, and a wind tunnel, permit us to continue our pursuit of research in wind effects on buildings and structures, windstorm damage

economics, wind characteristics in hurricanes and tornadoes, the economical design of shelters, soil erosion, and wind energy.

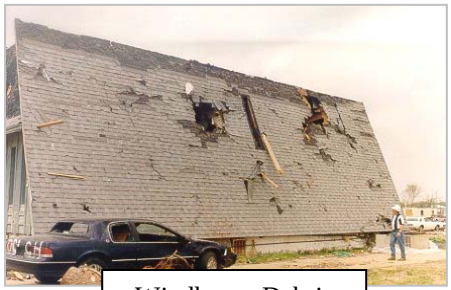
Over the past three decades, WISE Center personnel have pursued collaborative wind research projects with agencies, organizations, and universities, including NIST, the National Science Foundation (NSF), the Federal Emergency Management Administration (FEMA), the National Oceanic and Atmosphere Agency (NOAA), Texas Department of Insurance, Colorado State University, University of Western Ontario, Johns Hopkins University, Clemson University, University of Florida, Texas A&M-Kingsville, and the University of Oklahoma. In the following, a synopsis of research areas of damage documentation, storm shelters, wind effects, standards and codes, wind characteristics, and technology transfer/education are given. The synopsis gives a brief description of the research followed by bulleted items of accomplishments and challenges.

Damage Documentation

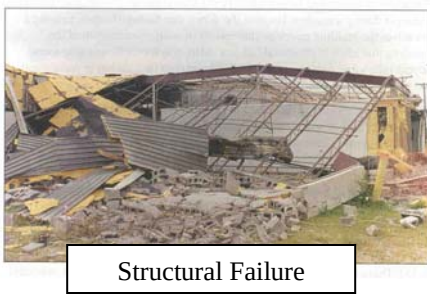
Documentation of damage to buildings in Lubbock following the 1970 tornado and the comprehensive report that was published was the first step in Texas Tech's gaining recognition and credibility in damage mitigation research. Damage documentation studies have continued in most of the extreme wind events that have occurred since 1970. Over 130 documentations have been completed, and a large number of photographs and reports have been archived. Information from the archive has been used extensively in seminars, publications, and outreach to the professional design community. The library of the late Dr. Ted Fujita, noted scientist and researcher (originator of F-scale rating for tornadoes) at the University of Chicago, was recently donated to Texas Tech, further enriching this valuable resource.

Lessons Learned

- Central portion of building is the safest
- Opening windows is counterproductive (impacted NWS instructions)
- Low-rise buildings of wood, masonry, light metal fail structurally
- Cladding damage is common
- Debris is abundant in urban areas
- Costly business interruptions are common
- Content damage is extensive



Windborne Debris



Structural Failure

Structural Failure

Cladding Failure

Debris

Business Interruption

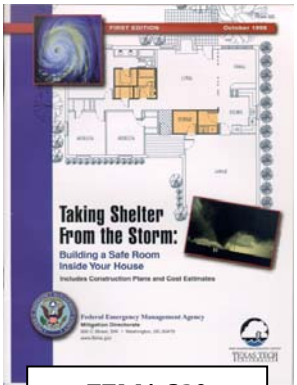
Content Damage

Challenges/Opportunities

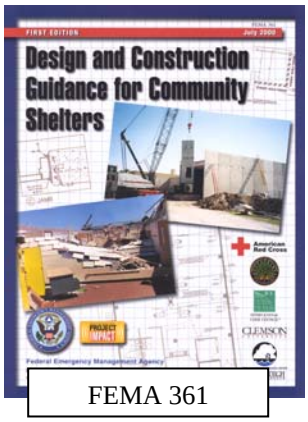
- Collection of statistical data
- Archiving cost data on consistent basis
- Aerial and satellite imagery documentation
- Developing accessible user-friendly data retrieval system

Storm Shelters (Safe Rooms)

Although the concept of the aboveground storm shelter emerged in the 1970s, widespread utilization followed the 1998 publication and distribution of FEMA Publication 320, *Taking Shelter from the Storm – Building a Safe Room Inside Your House*. Soon to follow was FEMA Publication 361, *Design and Construction Guidance for Community Shelters*. Rapid growth of the shelter industry was stimulated by the incentive grant program in Oklahoma following the Oklahoma City tornadoes of 1999. Emerging quality issues in shelter construction led to formation of the National Storm Shelter Association and development of an industry standard (available at www.NSSA.cc). The International Code Council is now developing a national consensus standard for storm shelters. Completion is expected in 2005.



FEMA 320



FEMA 361

Accomplishments

- Developed designs with conservative wind loads
- Bridged gap between research and implementation
- Designed and built state-of-the-art debris impact facility
- Provided design input to FEMA 320 and 361 publications

Debris Launcher

Challenges/Opportunities

- Optimize site-specific designs for economy
- Foster quality in shelter construction – standards and codes
- Reduce hurricane evacuation with in-home shelters
- Change mindset of public for shelters
- Define incentives to build shelters in existing and new buildings
- Establish programs to fund shelter construction for low income people

Wind Effects

The windy environment in the Lubbock area has permitted us to establish the Wind Engineering Research Field Laboratory (WERFL). A full-size building and a meteorological tower permit measurement of wind pressure data in natural winds. The WERFL facility was an impetus to the pursuit of a cooperative program (funded by NSF) with Colorado State University, which tested the same building in their wind tunnel to improve testing technology.

Innovative testing in the field using a C-130 Hercules aircraft permitted testing of full-size buildings in controlled high winds (gust up to 100 mph). Testing of real buildings to failure in fluctuating winds (not yet tested) will allow us to understand component resistances and progressive failure modes. This understanding leads to credible wind loss models.

CSU Wind Tunnel

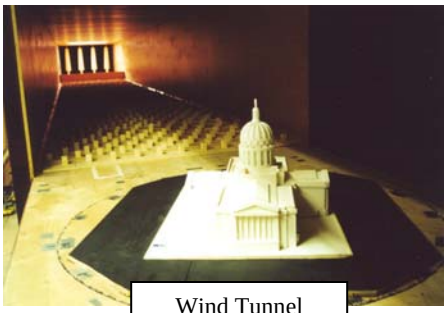
WERFL

Accomplishments

- Developed unique WERFL for wind effects
- Measured pressures from natural wind on a building
- Pursued cooperative NSF-funded program with CSU
- Assisted in improving wind tunnel technology
- Tested full-scale building with C-130 prop wash

Challenges/Opportunities

- Make WERFL accessible to researchers worldwide
- Develop facility to test full-size buildings to failure
- Build testing facilities for frame and component resistances
- Improve wind tunnel technology for component testing



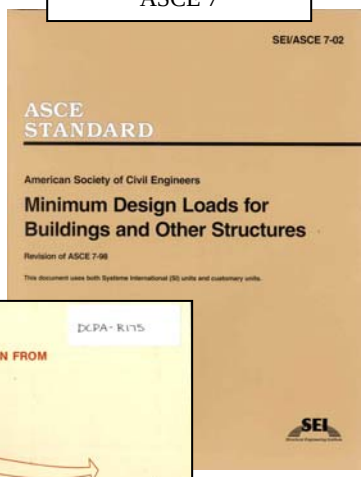
Wind Tunnel

Standards and Codes

Accredited standards provide a foundation for building codes that establish expectations of quality in the constructed environment. Accurate data is fundamental to establishing reliable standards, forming the basis for codes and ultimately the design of buildings. Consistency of codes, and hence the consolidation of model codes, is important to the design of safe economical buildings. Guidelines based on research permit professionals to design for situations that are beyond codes.

C-130 Testing

ASCE 7

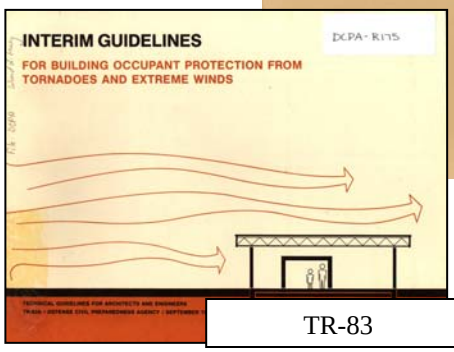


Accomplishments

- ASCE 7 Standard is based on physics and scientific data
- One wind load standard is developed for the country
- Model codes are consolidated into one model code
- Statewide building codes are being developed
- ICC/NSSA Standard for storm shelters is being assembled
- Safe areas in school guidelines have been developed

Challenges/Opportunities

- Calibrate prescriptive standards and codes
- Develop performance-based standards
- Develop risk management approach
- Develop cost-benefit models for mitigation measures



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Wind Characteristics

Knowledge of near-ground wind field in severe winds (hurricanes, thunderstorms, and tornadoes) and pressures and forces they impart on building components are essential to the design of safe economical buildings. The purpose of this knowledge is to simulate correct wind characteristics in wind tunnels. Current simulations of wind in wind tunnels do not reflect rapidly changing wind speeds in thunderstorms, downdrafts, or tornadoes or, to some extent, in hurricanes. Field measurements of wind in these storms, using stationary and protable towers, provide the necessary input to wind tunnels and, for the future, to computational fluid dynamics technology.

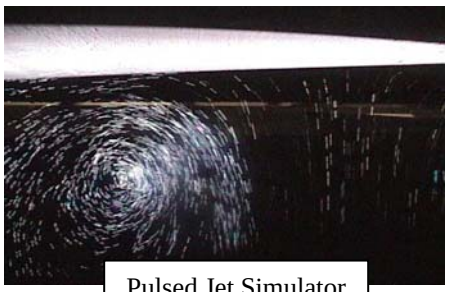
Accomplishments

- Measured ground-level wind characteristics in land-falling hurricanes
- Measured time and space correlation of winds in thunderstorms outflow
- Developed (preliminary) laboratory tornado simulator
- Performed initial experiments for downdraft effects on building

Tornado Simulator

Challenges/Opportunities

- Develop credible laboratory model of tornado
- Establish wind characteristic criteria for thunderstorm, tornado, and hurricane storms
- Develop wind tunnel that can simulate rapidly changing winds



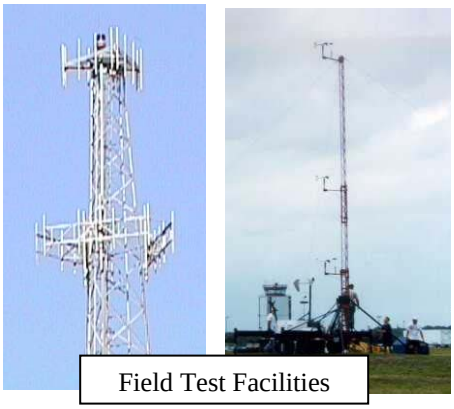
Pulsed Jet Simulator

Technology Transfer/Education

Research results become useful and valuable when they are implemented to improve the built environment or when they are used to influence human behavior and policy decisions. Information and outreach programs help to transfer technology to professionals and the public at large. We are only beginning to educate college and K-12 students to understand the perils of the wind hazard. The windstorm poses complex problems, and an interdisciplinary approach to approach to develop mitigation strategies and their implementation is needed.

Accomplishments

- ASCE continuing education courses are presented
- Seminars for professionals are presented
- Preview model for HAZUS (FEMA) has been developed
- A limited number of university graduates are produced



Field Test Facilities

Challenges/Opportunities

- Provide information for public, emergency personnel, and decision makers
- Produce graduates and professionals versed in windstorm disasters
- Complete FEMA/HAZUS model for the wind hazard
- Develop and Implement Interdisciplinary educational program

Reports Cited

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